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REVIEW AND ANALYSIS OF TELEMETRY LINK DATA BY TYPE AND OCCURRENCE OF DEVIATIONS

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-64-131

AUGUST 1964

R. J. Williamson

Prepared for

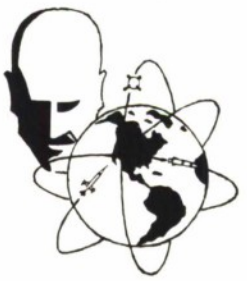
DIRECTORATE OF AEROSPACE INSTRUMENTATION

ELECTRONIC SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

UNITED STATES AIR FORCE

L. G. Hanscom Field, Bedford, Massachusetts



Project 705

Prepared by

THE MITRE CORPORATION
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Contract AF19(628)-2390

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TYPE AND OCCURRENCE OF DEVIATIONS

ABSTRACT

The scope of this document is contained in the title. The approach used is to plot or tabulate the number of occurrences of the different types of deviations in IRIG Document No. 106-60 Telemetry Standards (revised June 1962). The general trends indicated by these tables and graphs are discussed for nine general classes of deviations. Further reports will indicate the proposed handling of this and any additional data.

REVIEW AND APPROVAL

This technical documentary report has been reviewed and is approved.

ROY D. RAGSDALE
Colonel, USAF
Director, Aerospace Instrumentation

CONTENTS

ILLUSTRATIONS

REVIEW AND ANALYSIS OF TELEMETRY LINK DATA BY TYPE AND OCCURRENCE OF DEVIATIONS

SECTION I
INTRODUCTION

The revision of June 1962 to IRIG Document No. 106-60 Telemetry Standards is the only document that can be used as a criterion for evaluating the present telemetry links on the various programs. Therefore, the deviations referred to in this report are those values that do not adhere to this standard.

Although the data used here is more than a year old and has a few omissions, there is enough information to include most of the different types of deviations that may exist in all of the present telemetry programs. Some of the omitted data concerning the Space Systems Division (SSD) programs is not available at this time, so that information on all spacecraft programs is not complete. To this extent, the graphs should not be taken as the present status, but as these graphs are modified to include the missing data, they will indicate the trends for deep space telemetry also. The number of links used varies from graph to graph because of the omitted data on some links. The magnitude of the problem is displayed by the number of occurrences shown for each type of deviation.

The majority of types of deviations are tabulated in Tables 1 and 2 or shown in Figs. 1 through 10. Of course, where the basic system itself is completely non-standard there is no yardstick to use to determine the detailed deviations. It is believed that there are many more PCM links in use than are available in the present data, so that only one graph (Fig. 7) was plotted for this format.

SECTION II

OCCURRENCE OF THE VARIOUS TYPES OF TELEMETRY FORMAT BASED ON 167 LINKS

OCCURRENCE OF STANDARD FORMATS

The first group of standard formats in Table 1 reflects the high percentage of PAM/FM/FM and secondly the high percentage of FM/FM. The predicted increasing trend to various PCM formats is not reflected from this data.

OCCURRENCE OF NON-STANDARD FORMATS

The second group gives an insight to the use of non-standard formats. Some of the types indicate a combination of those that are standard.

UNDETERMINED FORMATS

Most of this data was taken from PRD's which, in general, are not as fully extended as desirable.

Table 1

Occurrence of the Various Types of Telemetry Systems

Occurrence	Standard Systems	Approximate Percent of Total Links
87	PAM/FM/FM	52.0
17	FM/FM	13.1
9	PDM/FM/FM	5.4
7	PCM/FM	4.2
3	PDM/FM	1.8
2	FM/PM	1.2
125		77.7
	Non-Standard Systems	
4	FM/AM	2.4
4	PCM/PM/PM	2.4
4	PDM/AM	2.4
4	PDM-PAM/FM/FM	2.4
3	PCM/FM/FM	1.8
3	CW	1.8
3	PCM-PAM/FM/FM	1.8
2	PDM/FM/FM + Digital	1.2
2	FM/FM-PAM/FM/FM (alternate)	1.2
1	FM/FM/FM	0.6
1	PM/FM	0.6
1	PPM/AM	0.6
1	FM	0.6
1	PCM/PS/PM	0.6
1	PPM-PAM/FM/FM	0.6
1	PCM/FM + FM/FM	0.6
36		21.6
	Systems Lacking Information	
1	?/FM/FM	0.6
1	PM	0.6
1	TV/FM	0.6
1	TV	0.6
1	PAM or PDM/FM/FM	0.6
1	PDM/FM or FM/FM	0.6
6		3.6

SECTION III

NON-STANDARD RF CARRIER FREQUENCY BANDS

The standard frequency band in the past has been from 216 to 260 mc. By 1970, this band is to be replaced by the 1435 to 1535-mc and 2200 to 2300-mc bands, according to a DOD directive issued in 1958 by the Joint Communication Electronics Committee of the Joint Chiefs of Staff. The present data does not reflect any use of either of these latter bands.

Twenty-nine links used non-standard frequency bands, which, in turn, are divided into seven groups (see Table 2). Of these, only Groups II, IV, and V have been assigned at the Geneva Conference of ITU (1963)* for international use for space purposes. Groups VI and VII result from going to higher frequencies in order to transmit through plasma, while Group III is used with Group IV for two-way transmission, and Group I is an early system frequency band.

Table 2

Non-Standard RF Carrier Frequency Bands

Group	Approximate RF Frequency Band (mc)	Occurrence
I	108	4
II	136	9
III	375	2
IV	400	4
V	960	3
VI	5,000	5
VII	13,500	2

*The actual bands closest to these approximate values are: 136 – 138, 400.05 – 402, and 900 – 960 mc.

SECTION IV

NON-STANDARD COMMUTATION

The non-standard commutation requirements, which include the combination of input samples per frame (channels) plus their frame rates, are shown in Fig. 1. Although Table 1 shows only 97 links of some type of PAM formats, as listed under type modulation in the PRD's, it was obvious from reviewing the data that 20 additional links used at least one subcarrier of PAM type modulation. The data was taken from 117 links, and includes some non-standard combined link formats such as PCM-PAM/FM/FM. This graph is arranged by number of occurrences rather than by commutation format.

Table 2 of the Standards contains specific values for both number of samples per frame and frame rates, such as 18 x 5. In Fig. 1, the values not specified in the Standards are enclosed by rectangles to indicate that portion of the commutation combination that is non-standard.

Table 2 of the Standards was chosen for mechanical commutators that existed in 1955. Modern electronic commutators can not only duplicate the mechanical commutators, but can furnish combinations not easily manufactured or maintained in the mechanical form. Since most programs would like to adhere to the Standards, it is possible that the development of the new electronic commutators based on the Standards may have been restricted to some degree.

The 60 samples per frame and 5 frames per second (60 x 5) commutation is the highest occurrence of the deviation from the Standards; however, the number of programs using this is only five. For example, four programs used 60 x 1 and 30 x 1.

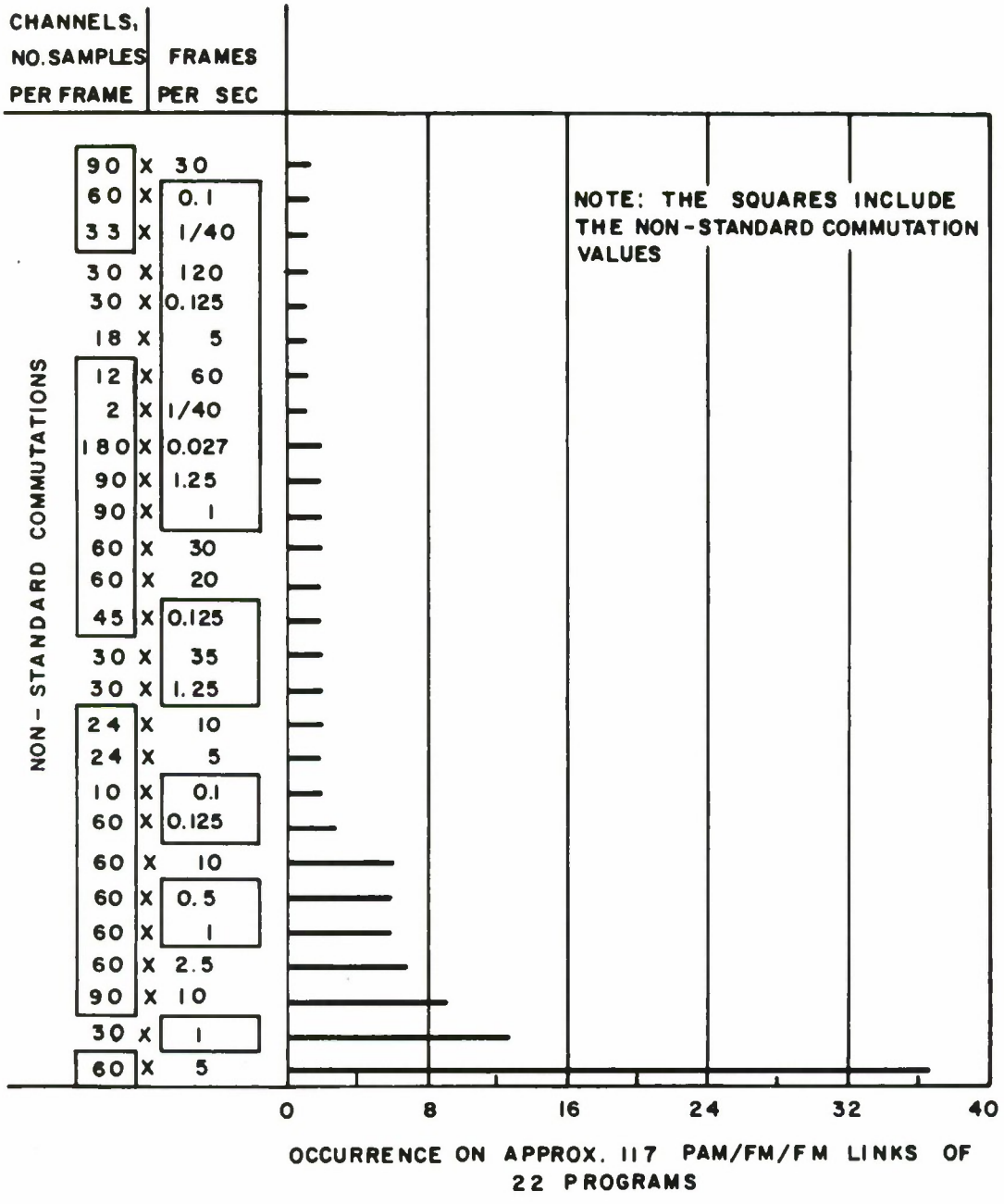

Fig. 1. Non-Standard Commutation Values with Reference to Table 2 of Telemetry Standards (IRIG Document No. 106-60)

A review of the other extreme of the graph concerning one or two occurrences indicates there are eight commutation combinations that occurred only once in a program and nine combinations that occurred twice in programs. This indicates a tendency to pick combinations at random, except, perhaps, for a tendency to double a standard value, such as changing the 30 x 5 to 60 x 5. For deep space telemetry, where the information rate may be justifiably reduced, there may be a trend to increase the number of channels, subject to the allowable commutation channel bandwidth.

SECTION V

NON-STANDARD FRAME RATES

The number of occurrences of non-standard frame rates, taken from 117 PAM/FM/FM links, is plotted in Fig. 2. The data is taken from any PAM subcarrier channel, including non-standard type systems. As noted from the graph, the tendency is to use lower frame rates, presumably in order to use the maximum number of channels and keep the pulse rate at a minimum.

The maximum number of occurrences was for a frame rate of 1 per second. The minimum frame rate of 2-1/2 is specified in Table 2 of the Standards. This 1-per-second frame rate can no doubt be designed into electronic commutators; however, some of the other extremely low rates shown in the graph do present a problem.

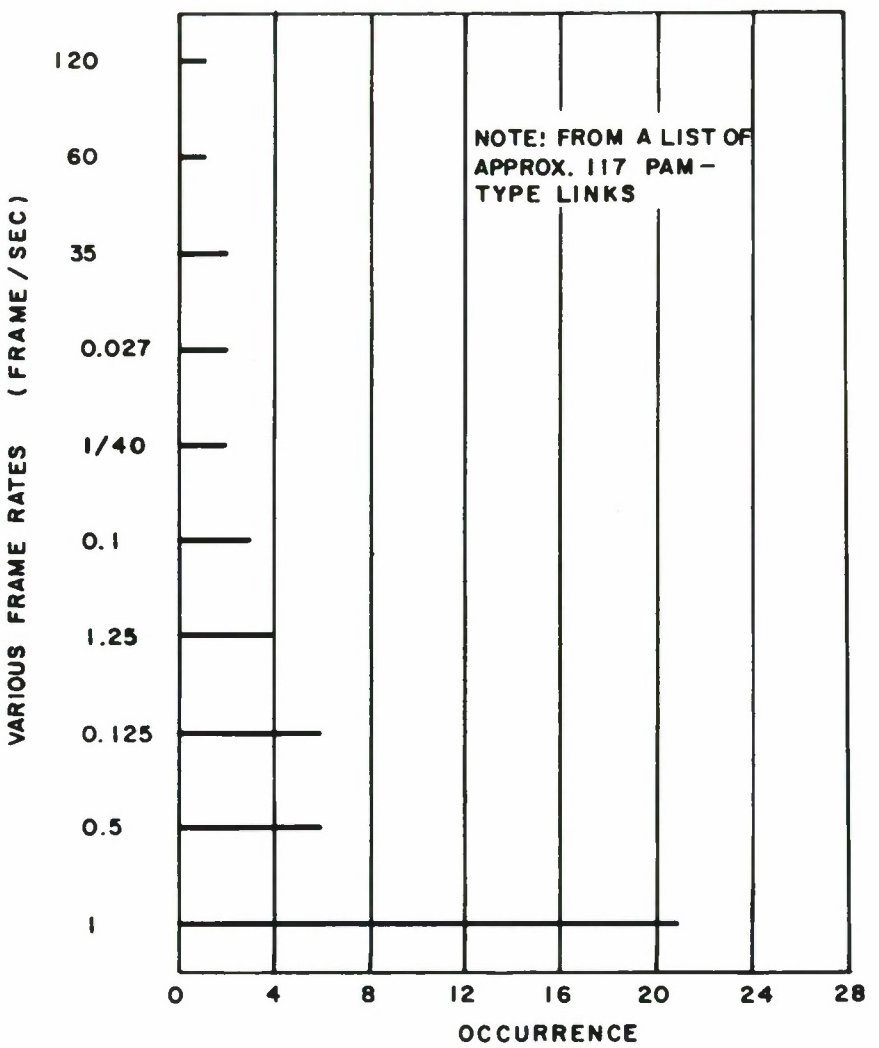

Fig. 2. Non-Standard Frame Rates of the Non-Standard Commutations with Reference to Telemetry Standards (IRIG Document No. 106-60)

SECTION VI

NON-STANDARD NUMBER OF SAMPLES/FRAME (CHANNELS)

The number of occurrences of non-standard samples per frame taken from 117 links is plotted in Fig. 3. The maximum occurrence was for 60 samples per frame, which is double the number allowed in Table 2 of the Standards. In some cases, there may have been a need for transmission of much low-frequency transducer data, but, no doubt, there is a tendency by many designers to adhere as closely as possible to the standard allowable channels. With the present "state-of-the-art," there is no problem in designing any commutator with many more channel inputs than even 60.* Therefore, it would appear that more than 60 samples per frame could be allowed in the future, provided the combinations were limited.

Some of the minimally used samples per frame, such as 2, 12, 33, and 45, should be investigated and, no doubt, could be eliminated in the future.

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*"Data-Scanning Semi-Conductors or Metallic Conductors," E. Donath and M. Kranzler, Proc. of 1963 NTC.

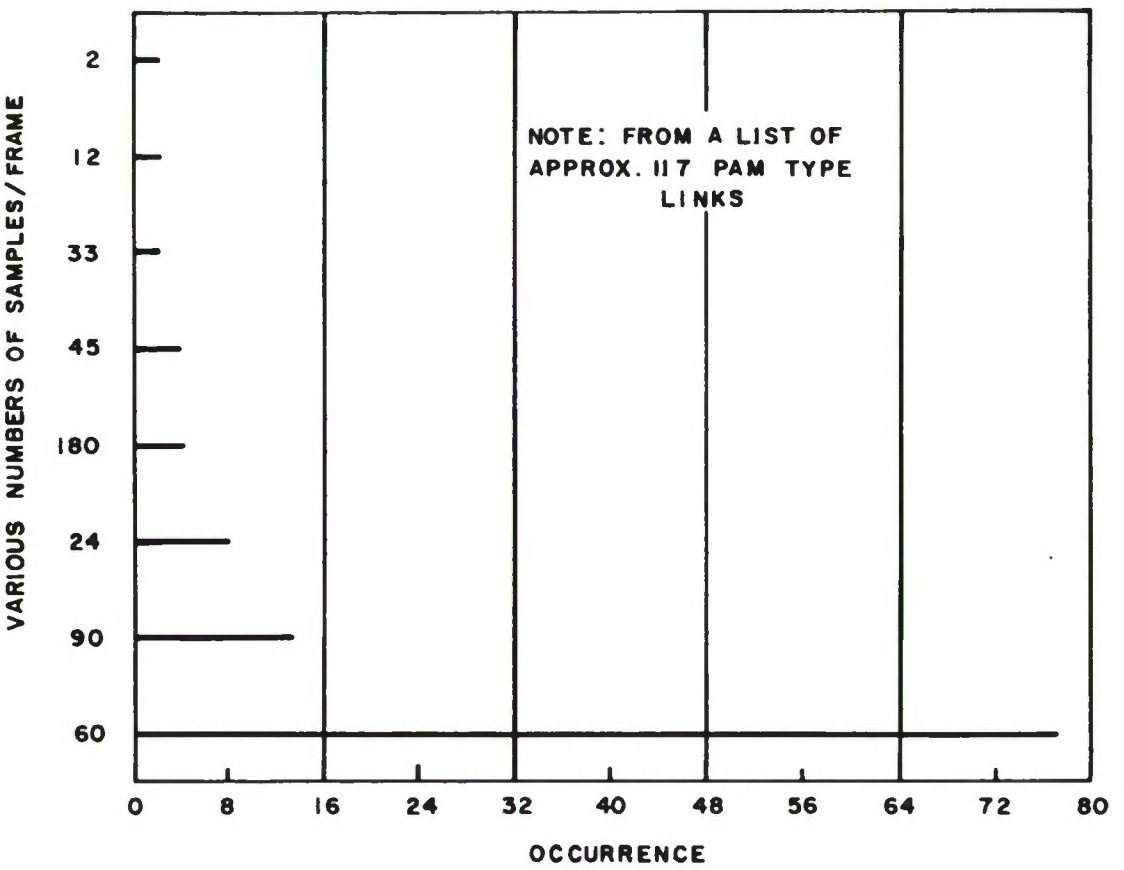

Fig. 3. Non-Standard Samples per Frame of the Non-Standard Commutations of Telemetry Standards (IRIG Document No. 106-60)

SECTION VII

NON-STANDARD PULSE RATES (SAMPLES/SECOND)

In Table 2 of IRIG Document No. 106-60 Telemetry Standards, a list of commutation specifications for Automatic Decommutation gives the samples per frame and frame rate which define the pulse rate. The recommended subcarrier frequencies and deviations are also listed. The commutation of subcarrier channels is not listed below 10,500 c.p.s.

USE OF ± 7.5 PERCENT DEVIATION PORTION OF TABLE 1, STANDARDS, IN RELATION TO COMMUTATION

The specified pulse rates above 10,500 c.p.s. in Table 2 of IRIG Document No. 106-60 are plotted and joined by the solid line curve in Fig. 4. In an earlier IRIG Standard, No. 102-55, a maximum commutation rate was given which is equal to the frequency response times 0.5, as given in Table 1 of Document No. 106-60. These values are plotted in Fig. 4, and a dashed line is drawn to show these values. With certain precautions and poorer acceptable accuracies, pulse rates up to these values, and even higher, could be used, but not by the present Standards. In addition to these curves, the pulse rates exceeding the present Standards (solid line in Fig. 4) and their number of occurrences are plotted.

A very few pulses have rates extremely in excess of the standard or even of the dashed line (IRIG 102-55), labelled feasible limit (Fig. 4).

USE OF THE ± 7.5 PERCENT DEVIATION PORTION OF TABLE 1, NOT TO BE COMMUTATED (See Table 2, IRIG 106-60)

Since commutation below 10,500 c.p.s. is not allowed by Table 2 of the Standards, all pulse rates on subcarriers below this frequency are plotted in Fig. 5. The dashed line is derived from the same source as that in Fig. 4.

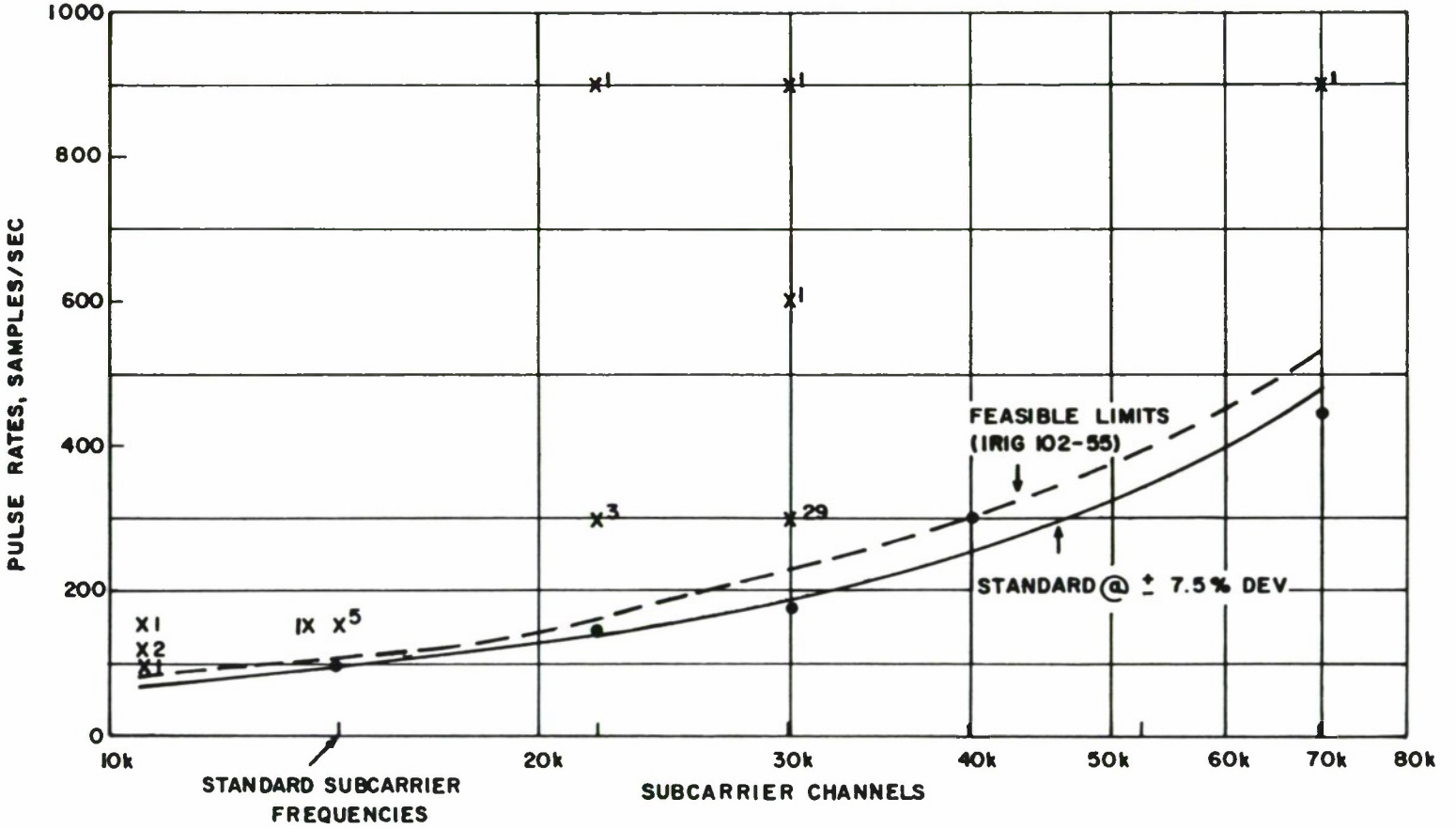

Fig. 4. Non-Standard Pulse Rates per Table 2 (IRIG Document No. 106-60), ± 7.5 Percent Deviation Only

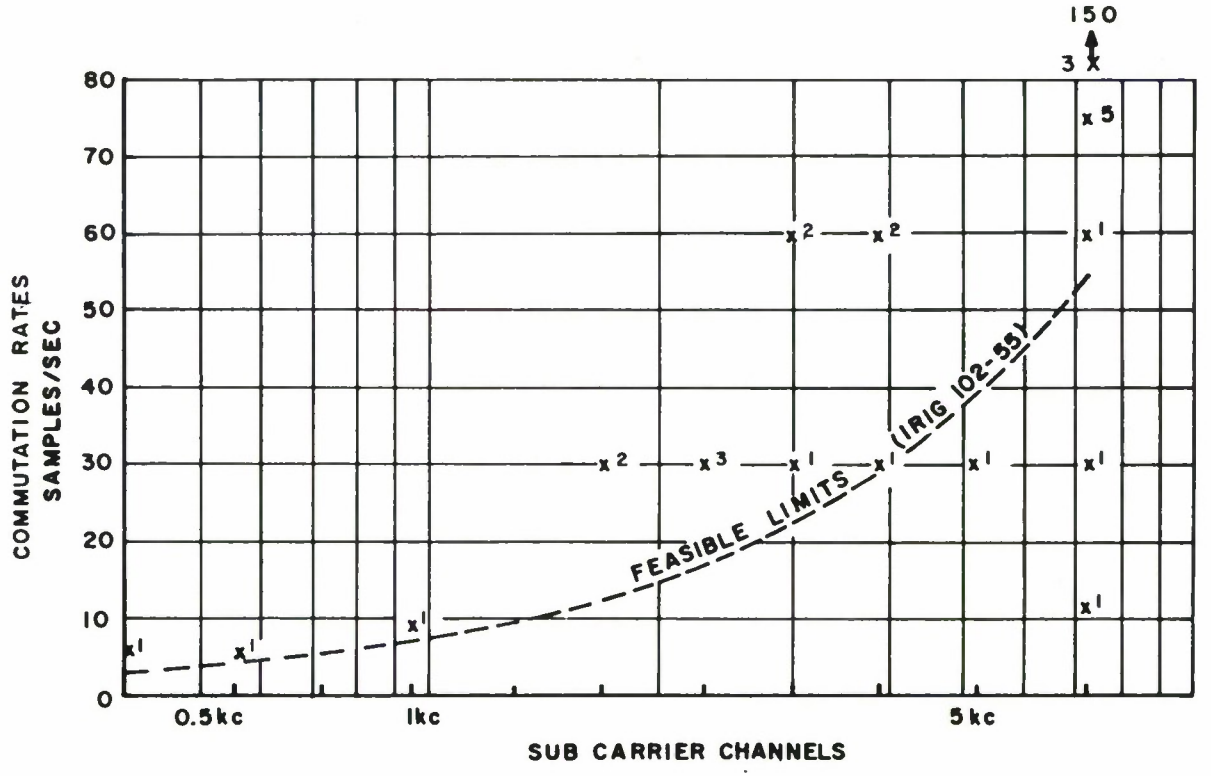

Fig. 5. Non-Standard Pulse Rates on Prohibited Subcarriers per Table 2 (IRIG Document No. 106-60), ± 7.5 Percent Deviation Only

THE ± 15 PERCENT DEVIATION PORTION OF TABLE 1, STANDARDS, IN RELATION TO COMMUTATION

A plot of the ± 15 percent deviations, similar in nature to Fig. 4 for the ± 7.5 percent deviation cases, is shown in Fig. 6. There are very few that exceed the commutation pulse rate. From this, it might be surmised that once a designer realizes an excessive pulse rate problem he can solve it, within the limit of the Standards, by using the ± 15 percent deviation in most cases. However, there was one case of a pulse rate of 3600 at ± 30 percent deviation. With the present limited data substantiating this use, it is difficult to make any comment.

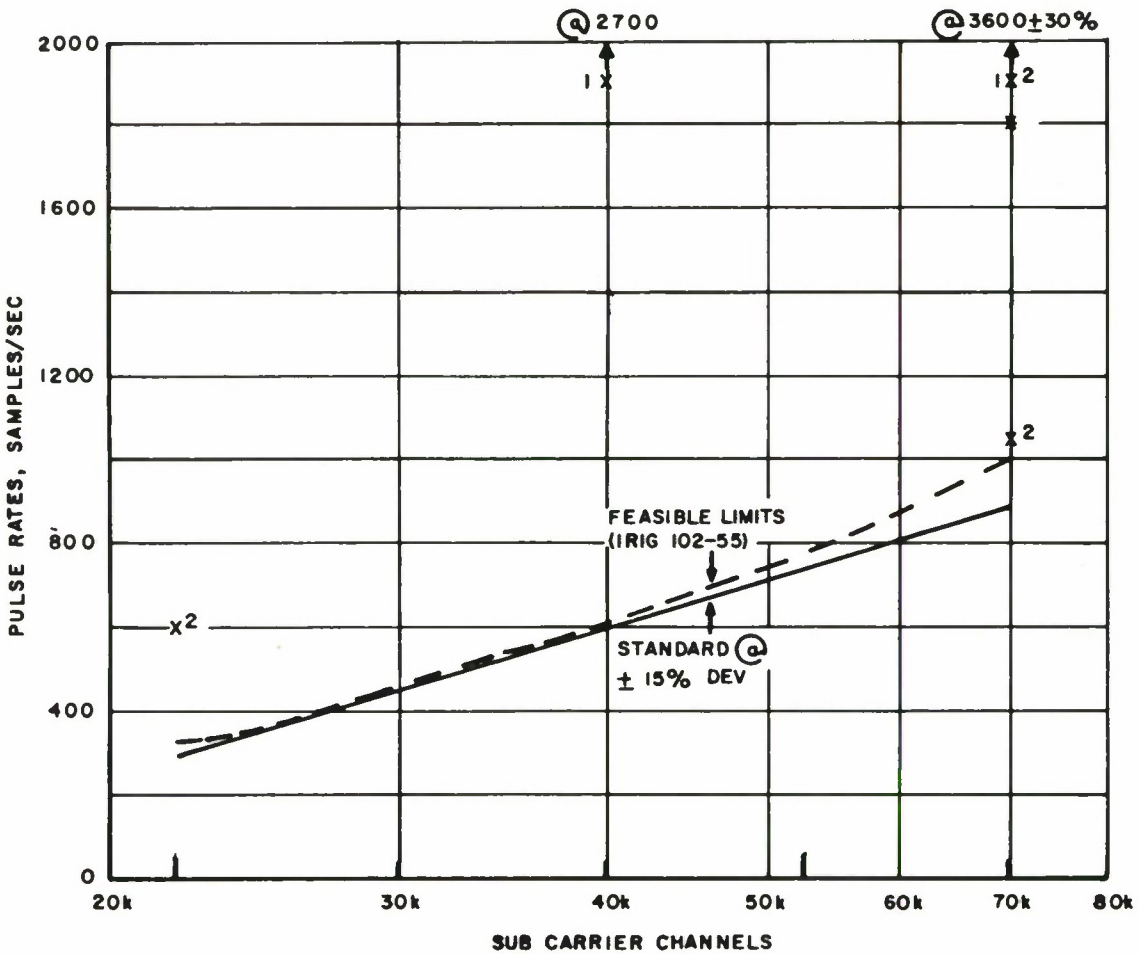

Fig. 6 Non-Standard Pulse Rates per Table 2 (IRIG Document No. 106-60), ± 15 Percent Deviation

SECTION VIII

NON-STANDARD PCM/FM BITS/FRAME

Under paragraph 5.4, "Word and Frame Structure," in the Standards, there is specified a maximum bits/frame of 2048, including those used for frame synchronization. The bits/frame in the PCM/FM systems were only specified for five links out of a total of seven. As noted in Fig. 7, the bits/frame for these links were all greater than the maximum allowed in the Standards.

There were also seven additional PCM format variations, such as PCM/FM/FM and PCM-PAM/FM/FM, for which there are no standards.

Phase II of the Telemetry Systems Standardization Program calls for an investigation into such items as maximum bits/frame, bit rate stability, synchronization techniques and Standards as a whole.

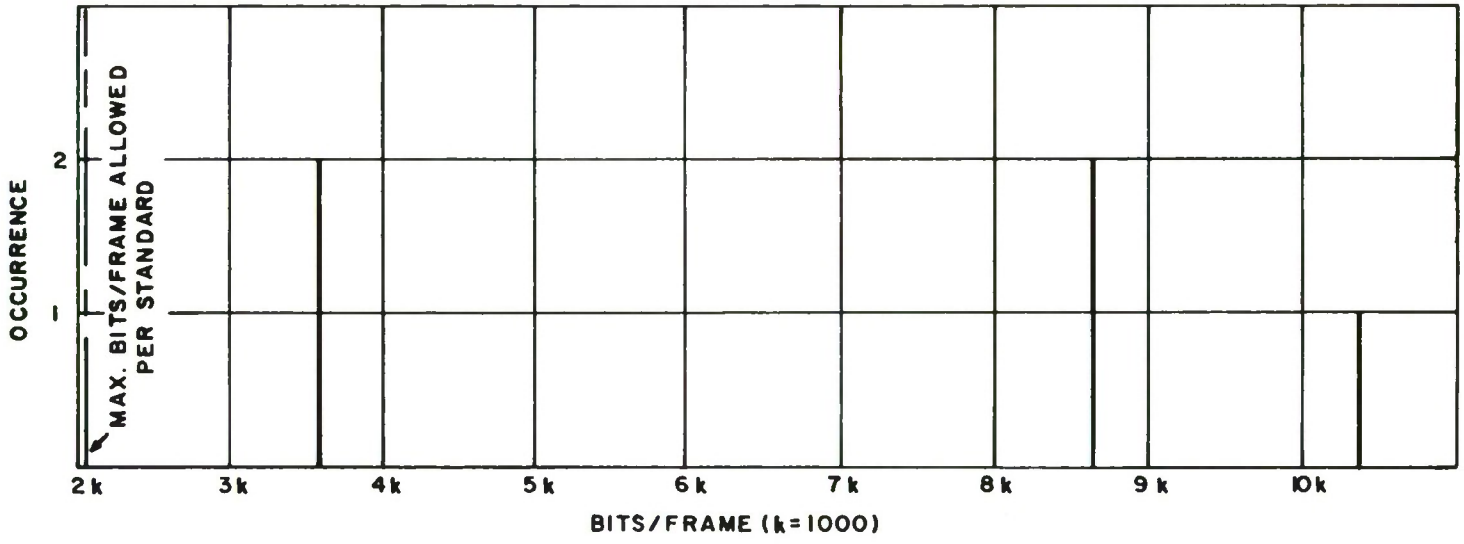

Fig. 7. Non-Standard Bits per Frame, per IRIG Document No. 106-60, for PCM/FM Links

SECTION IX

NON-STANDARD SUBCARRIER FREQUENCIES

Approximately 40 percent of the programs used non-standard subcarrier frequencies; several used 54 and 83.5 kc for the same applications throughout all phases.

Two links used the following group of non-standard subcarrier frequencies: 1.15 kc ± 2.2 percent deviation, 1.25 kc ± 2 percent, 1.35 kc ± 1.85 percent, and 1.45 kc ± 1.73 percent. The ratios between these subcarriers are lower than the approximate 1.3 ratio used in the Standards, and a much lower deviation ratio than usual is used. One link used eight subcarrier channels between 164 and 1200 c.p.s., with no deviation ratio given. Other odd subcarrier frequencies used were 85, 100, and 98 kc.

The distribution of non-standard channels in Fig. 8 indicates a concentration of values above the highest standard, 70 kc, and around 1 kc. Also, there are channels even lower than the 400 c.p.s. subcarrier frequency.

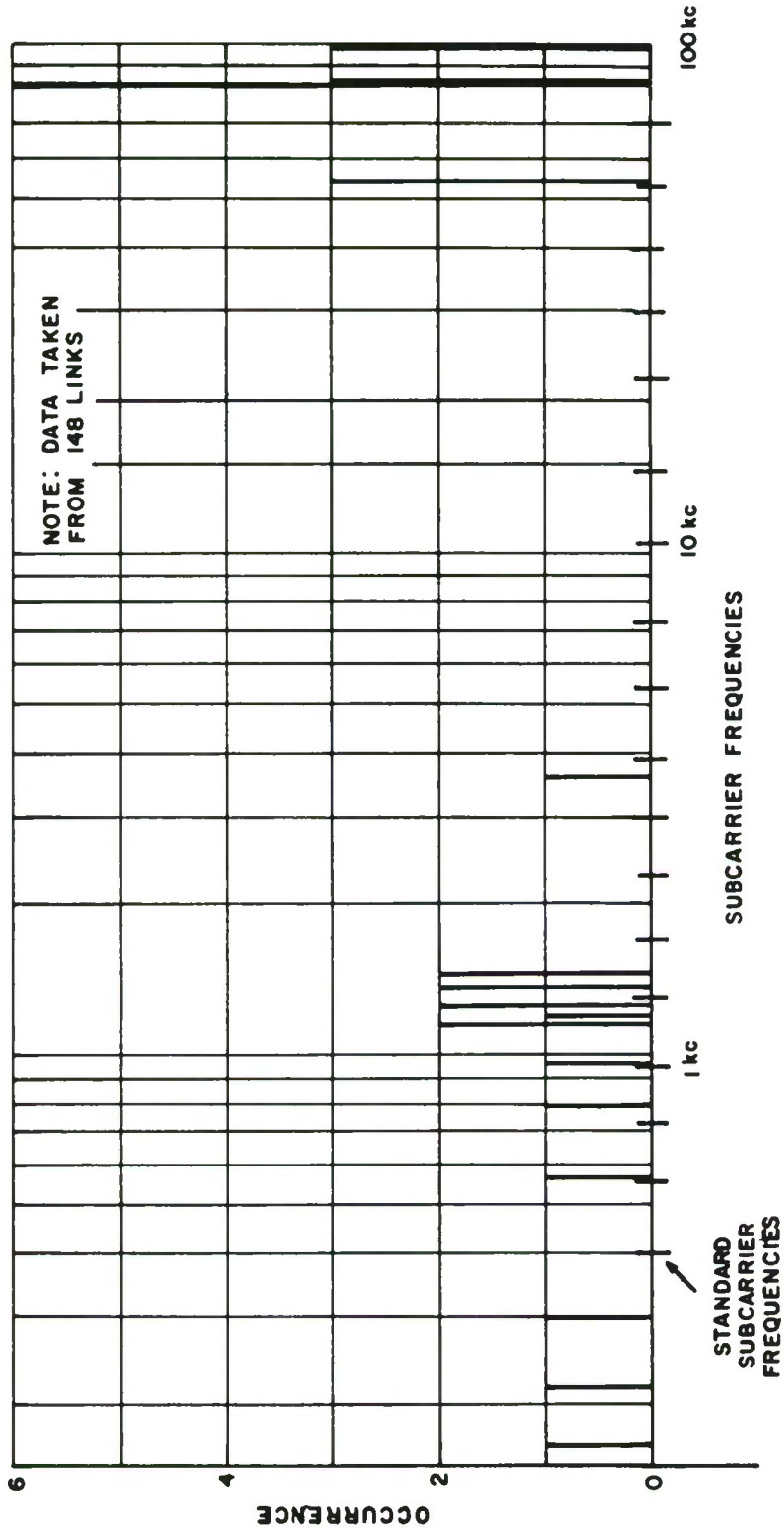

Fig. 8. Non-Standard Subcarrier Frequencies

SECTION X

BANDWIDTHS LESS AND GREATER THAN MAXIMUM ALLOWED VALUE

In the Standards, the modulated carrier for the present 216 to 260 mc band is not to exceed a 500 kc non-interference bandwidth. There is no statement as to use of bandwidths lower than this value, but for maximum signal-to-noise (S/N), the receiver IF bandwidth should obviously be adjusted for the transmitted modulation bandwidth.

Only 110 bandwidths were listed in 167 links, of which 69, or 63 percent, were not the maximum allowed 500 kc. The true meaning of these bandwidths will be investigated, but for the present we are assuming these are the requirements for the transmitter; i. e., the designer wants the improved S/N specified by the smaller bandwidth.

Out of the 110 links, 60 percent of the bandwidth requirements were lower than the specified 500 kc maximum (see Fig. 9). The predominating variation is the 300 kc bandwidth. If narrower bandwidths are desirable, and 300 kc is a suitable option, then, for example, the eleven 250 kc bandwidth requirements could no doubt be adjusted to, say, the 300 kc option.

Twenty-eight of the bandwidths that were greater or less than maximum allowable were specified for use with non-standard RF carriers. Most of these systems appear to need either extremely narrow or wide bandwidths. In considering Fig. 9, it should be remembered that non-standard RF carrier, narrow or wide band cases, are included. There is a two-decade spread of bandwidths within the "standard" 500 kc.

Figure 10 displays the information in Fig. 9, and also includes bandwidths greater than 500 kc. These cases, comprising 5.5 percent of the total would be considered a large deviation under Phase II of the Standardization Program.

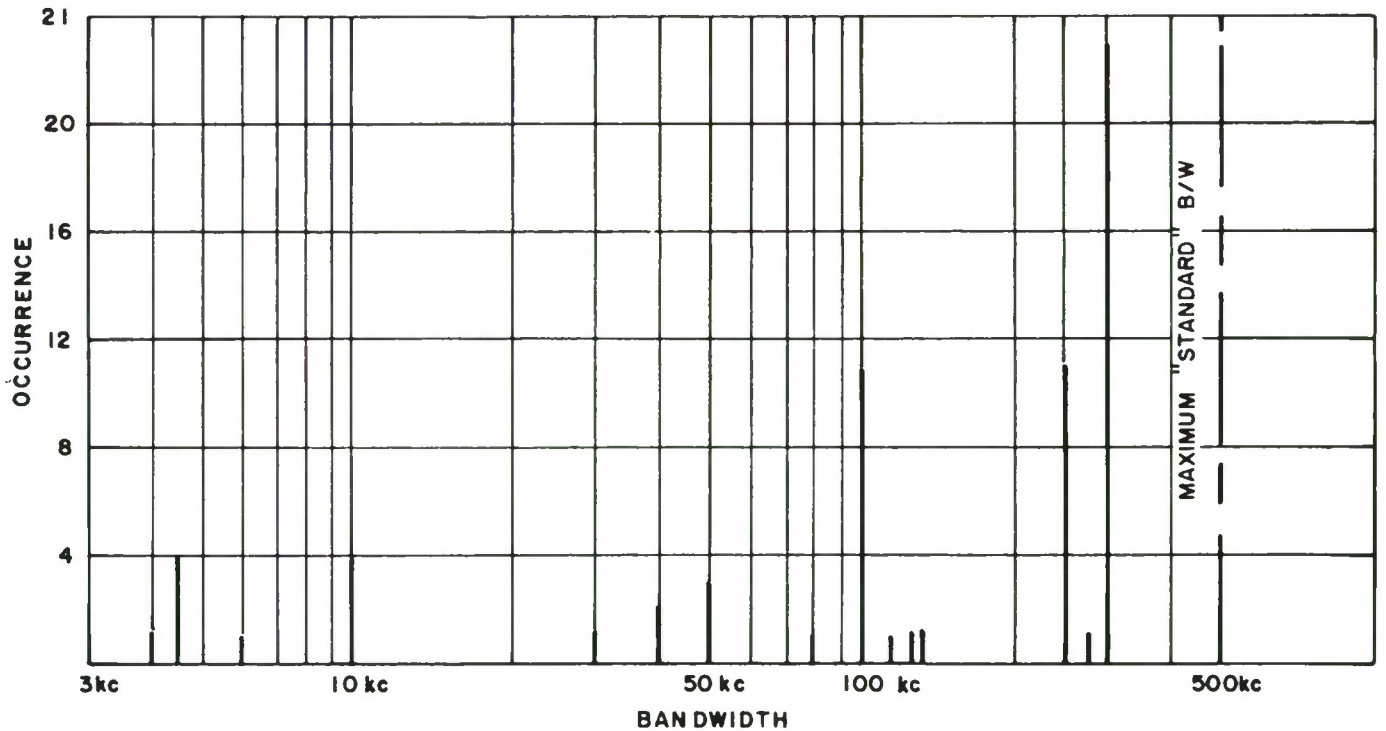

Fig. 9. Bandwidths Less than Maximum Allowed Value (up to 500 kc) – out of 110 Reported from 167 Links

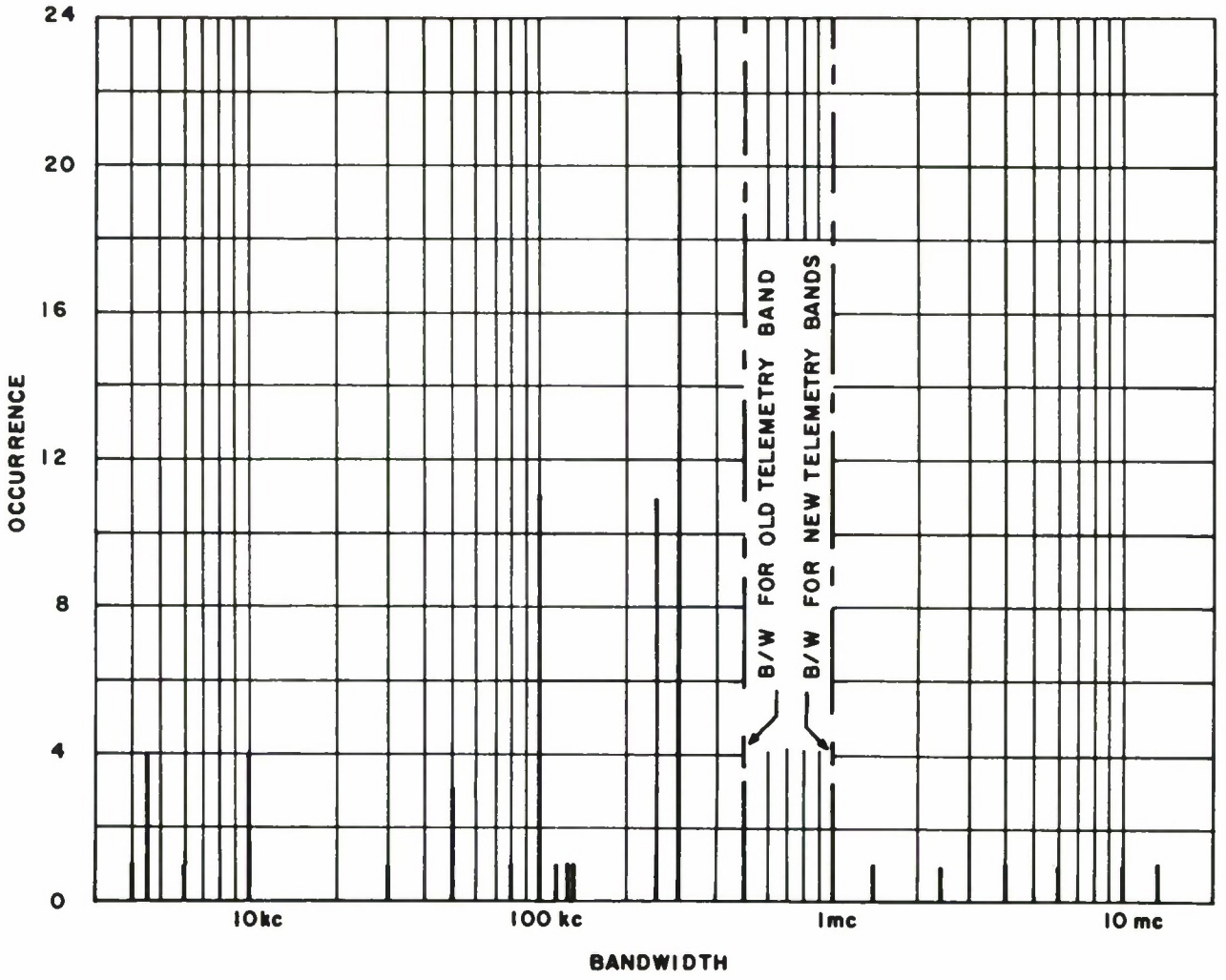

Fig. 10. Bandwidths Less and Greater than Maximum Allowed Value – out of 110 Reported from 167 Links

SECTION XI

NON-STANDARD ODDITIES, OF TWO TYPES

There are two deviations of varied types, which would be of little value in plotted form. For example, rather than the normal ± 7.5 or ± 15 percent deviations on the subcarrier frequencies, a few links used odd deviations such as ± 2, 2.2, 1.85, 1.73, 30 and 40 percent. Most of these appeared in combination with other deviation-types, such as non-standard subcarrier frequencies.

In 17 links, the 22 kc subcarrier at ± 15 percent deviation was used with the 14.5 kc ± 7.5 percent subcarrier. The latter should be omitted, as shown in Table 1 in the present Standards. Since the percent deviation was omitted from many of the subcarrier frequencies, there may be many more occurrences of this type of deviation.

Other types of deviations from the Standards may exist, but with information lacking, they are undeterminable until more complete information is obtained. When more information is available, it will be possible further to divide the present graphical data into missile, spacecraft, and propulsion-type applications.

SECTION XII

SUMMARY

In this report, the number of occurrences of seven types of deviations and their range of distribution are plotted graphically. In addition, there are two types of deviations discussed that were not worth plotting.

Table 1 displays the various system formats, while Table 2 shows radio carrier frequencies. Figures 1, 2, and 3 contain plots of the occurrences of the non-standard commutation combinations and their division into the frame rates and samples per frame, in that order.

For PCM types, there was a very limited amount of data; therefore, only the bits per frame relative to the standard limit were plotted in Fig. 7.

In Fig. 8, the occurrences of the non-standard subcarrier frequencies are plotted and their positions in the frequency spectrum relative to the present Standards indicated.

In Figs. 9 and 10, the occurrences and wide distribution of bandwdiths are shown, for those below the 500 kc limit, and for the total, respectively.

The various deviation ratios used other than the preferred ± 7.5 and 15 percent, and use of the 22-kc subcarrier frequency in a non-standard manner are discussed.

SECTION XIII

CONCLUSIONS

The intent of this report is not to arrive at firm recommendations at this time, but to display the various deviations from the Standards (or the norm) in terms of their occurrence and distribution. The degree of deviation was not a factor affecting the work. The following conclusions are drawn:

(1) This review shows that there is an urgent need to not only update the present data, but also to obtain more detailed design and use information. This is a continuing function of the Telemetry Systems Standardization Program.

(2) This work confirms the generally held opinion that the Standards need some revisions as to the specified values, and as to design/use parameters of the listed formats and systems, together with the inclusion of many format combinations that are obviously permissible (e. g., PCM/FM/FM). (However, these revisions must be made as the result of a carefully planned program of analysis, proposal, test, and development.)

(3) The occurrence of the different deviations from the Standards, and their relative magnitudes may show, in some cases, trends toward telemetry systems with more capability for present and future requirements, but they must be individually investigated in Phases I and II of the Standardization Program.

Finally, it is hoped that this report may stimulate sufficient interest from the many telemetry specialists, both on the programs and the ranges, so that they will make suggestions for the better accomplishment of the ESD/MITRE Telemetry Systems Standardization Program.

R. J. Williamson

R. J. Williamson

BIBLIOGRAPHY

Telemetry Standards, IRIG Document No 106-60 (Rev. 1, June 1962); Inter-Range Instrumentation Group of the Range Commanders Conference; EWSR-RCC, White Sands Missile Range, New Mexico.

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13. ABSTRACT

The scope of this document is contained in the title. The approach used is to plot or tabulate the number of occurrences of the different types of deviations in IRIG Document No. 106-60 Telemetry Standards (revised June 1962), The general indicated by these tables and graphs are discussed for nine general classes of deviations. Furhter reports will indicate the proposed of this and any additional data.

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